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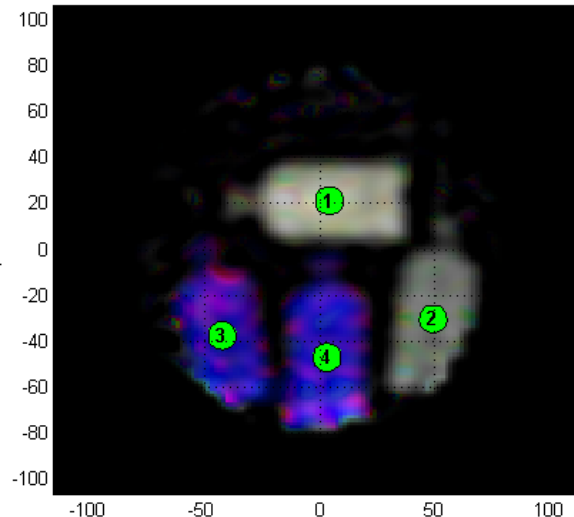
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What's in that bottle?

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What we'll talk about today

- A little about airport security, liquids, and LANL's role.
- MRI and X-ray and how we went from medical imaging to security screening.
- A couple of Oscar-nominated movies.
- Other cool X-ray stuff, computed tomography (CT) and 3D printing!



A familiar sight at airports





What is the main diagnostic tool for looking “inside things” at airports or otherwise....?

Why do we have to take our shoes off anyway?

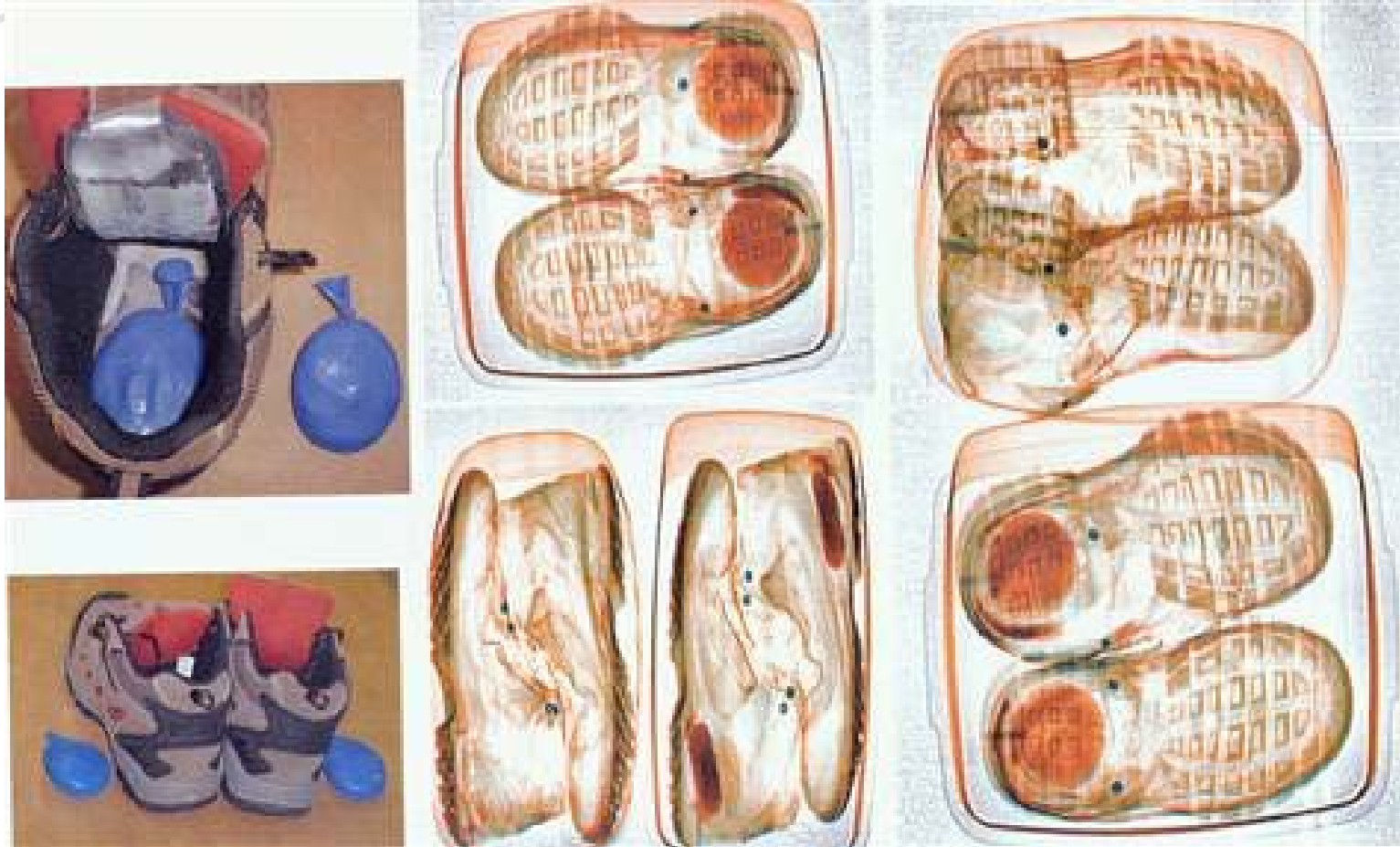
“People take off their shoes because there was a shoe bomber and because there’s intel about others who would use materials conveyed in shoes to get on an aircraft to do damage.” -Janet Napolitano, August 2009



Richard Reid aka “the shoe bomber”

X-ray





Transportation Safety Administration officials on Tuesday displayed a mock up of "Shoe Bomber" Richard Reid's shoes, left, along with X-ray images of the explosive-laden shoes and normal shoes.

http://www.msnbc.msn.com/id/14353942/ns/us_news-security/t/x-raying-shoes-effective-tsa-chief-tells-public/

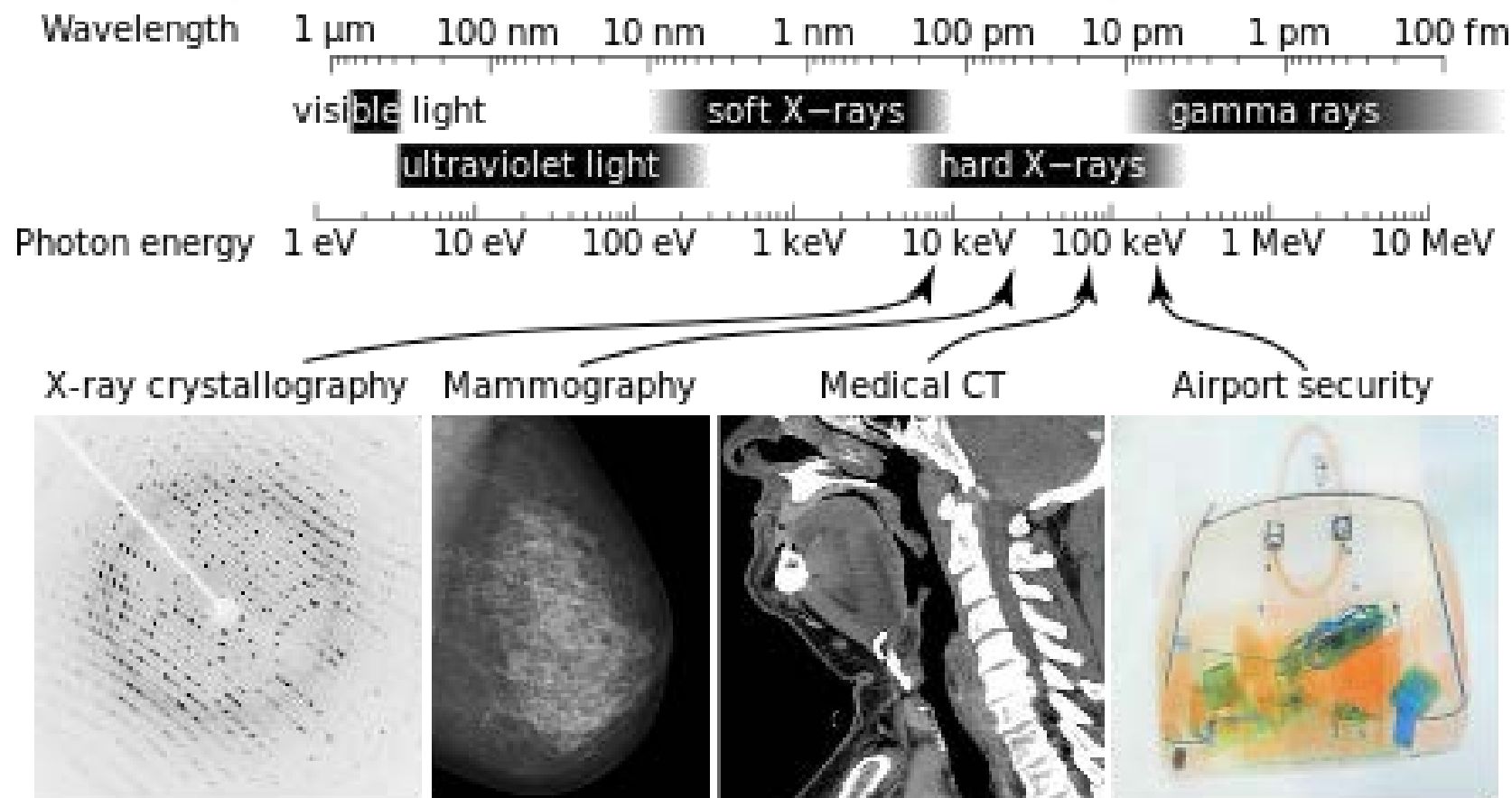


X-ray?





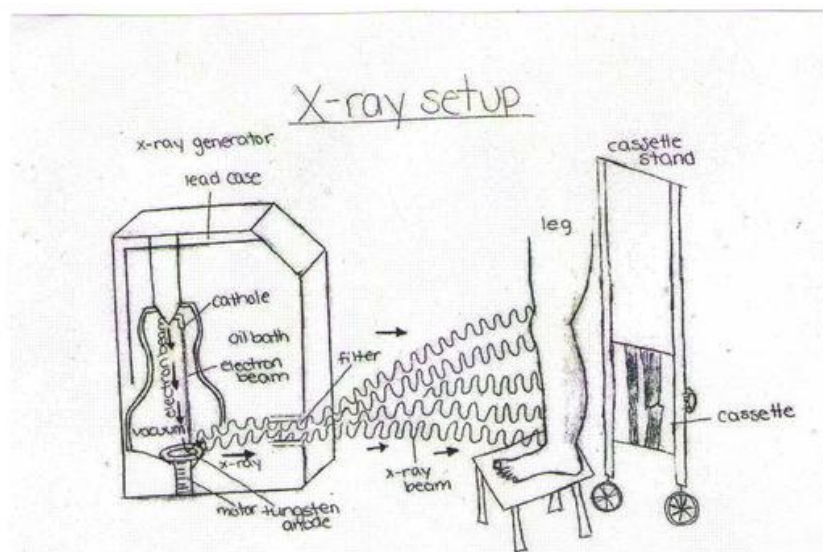
X-rays are just a higher energy version of visible light



<http://en.wikipedia.org/wiki/X-rays>

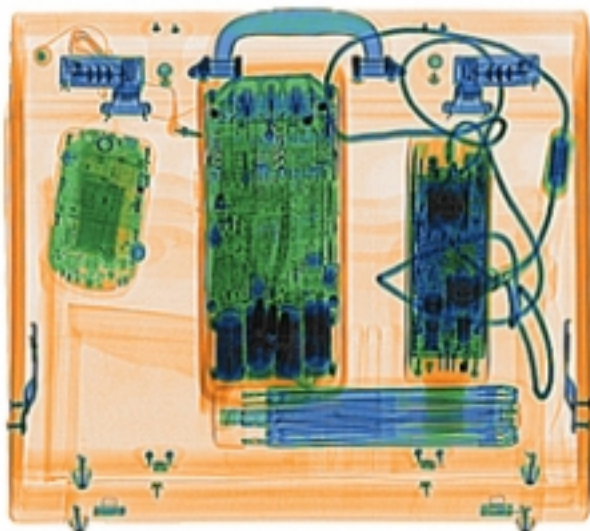


Medical X-ray Imaging

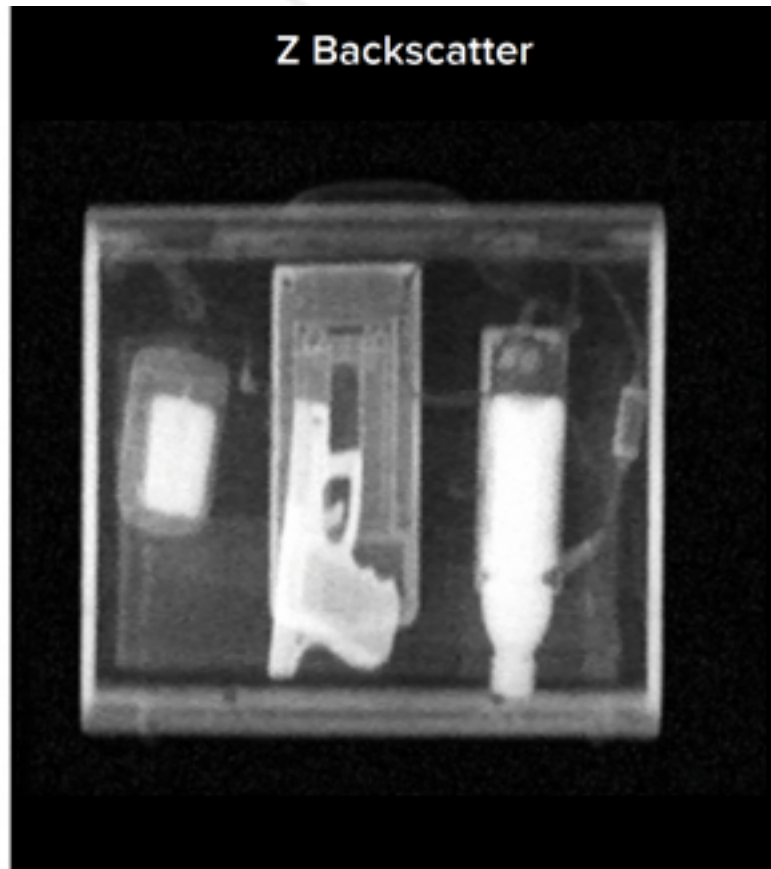


X-Ray for Security Screening

Dual-Energy



Z Backscatter



<http://as-e.com/products-solutions/parcel-inspection/checkpoint-mailroom-small-parcel/product/gemini-6040>

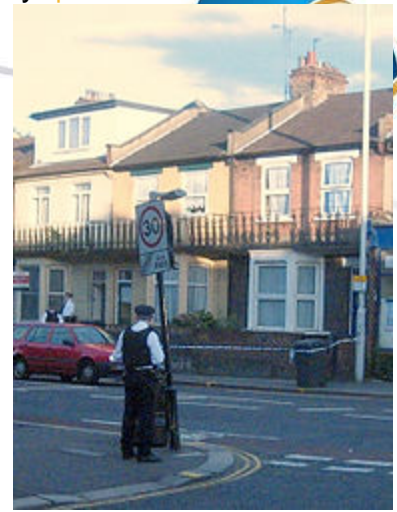
August 2006 London: an alleged terrorist plot was thwarted

The aim: assemble and detonate liquid explosives on planes

September 2009: three sentenced to life in prison.

Plot could have killed at least 1,500 people aboard.

Result: new measures prohibiting passengers from carrying all but small quantities of liquids and creams onto flights.





3-1-1: is it as stupid as it seems?

The problem is that there is presently NO non-contact and high throughput way to look at liquid explosives....

<http://www.howstuffworks.com/liquid-explosives.htm>



Because it's clear and oily, nitroglycerin would be easy to conceal in lotion or shampoo bottles.



How does the U.S. government react?

- TSA (Transportation Security Agency)
 - Responsible for keeping us safe while still letting us travel.
- DHS (Department of Homeland Security)
 - Oversees TSA, and helps provide guidance and technical solutions.
 - When DHS needs help, they ask for answers from industry and from...
- LANL and other science labs.

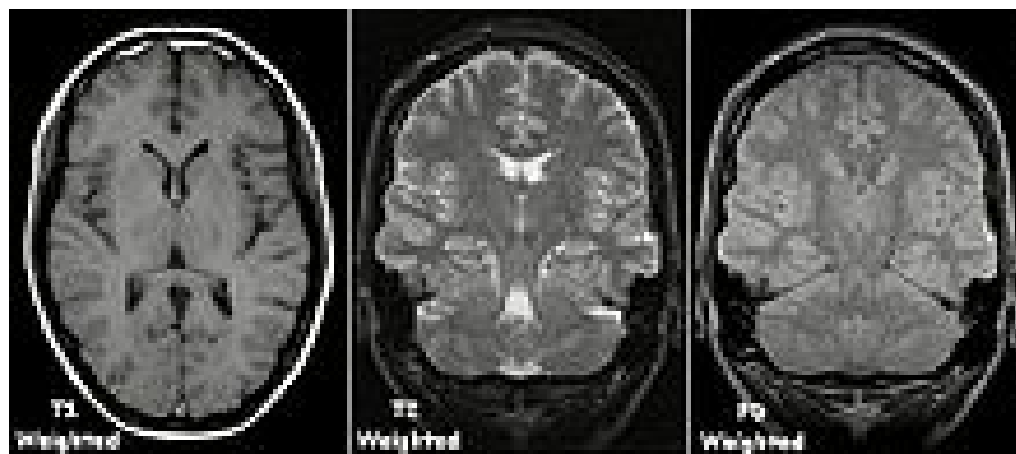


Shifting gears... back to medical imaging



X-ray is great for bones!

MRI is great for tissue!





Definitions...

because I always forget them

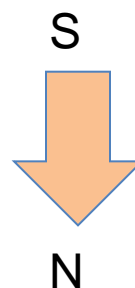
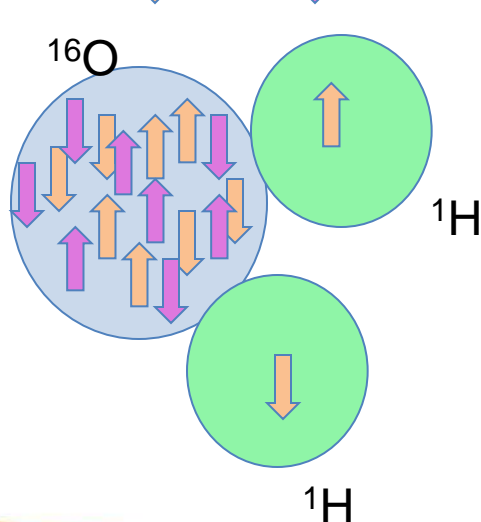
- NMR – Nuclear Magnetic Resonance
 - The basic magnetic signal from a substance
- MRI – Magnetic Resonance Imaging
 - Making an image showing how the NMR signal varies over an area of interest.
- ULF – Ultra Low Field
 - Doing NMR or MRI at much, much lower field strengths than is traditional.
 - More on this later



How NMR works



You are made up of atoms – which are made up of protons and neutrons. Mostly you are... water



The proton and neutron possess “spin” – they act like little magnets.



Hydrogen atoms react to external fields!



How Magnetic Resonance Imaging (MRI) works

- In NMR we excite **hydrogen atoms** so that they produce a magnetic signal that can be measured.
- The more hydrogen atoms in a sample material, the more signal we get.
- The **chemical environment** that the hydrogen atoms are in influences how fast the magnetic signal builds up (**T1**) and dies off (**T2**).
- In MRI we can make **images** of hydrogen density, T1 and T2 across a sample (or person).
- Different types of tissue have different T1 and T2, so **we can see different types of tissue.**



But what does MRI have to do with screening for liquids?

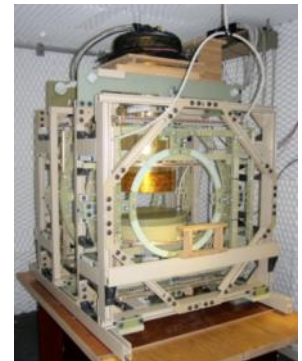
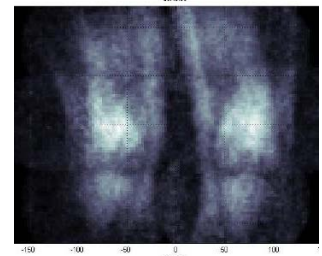
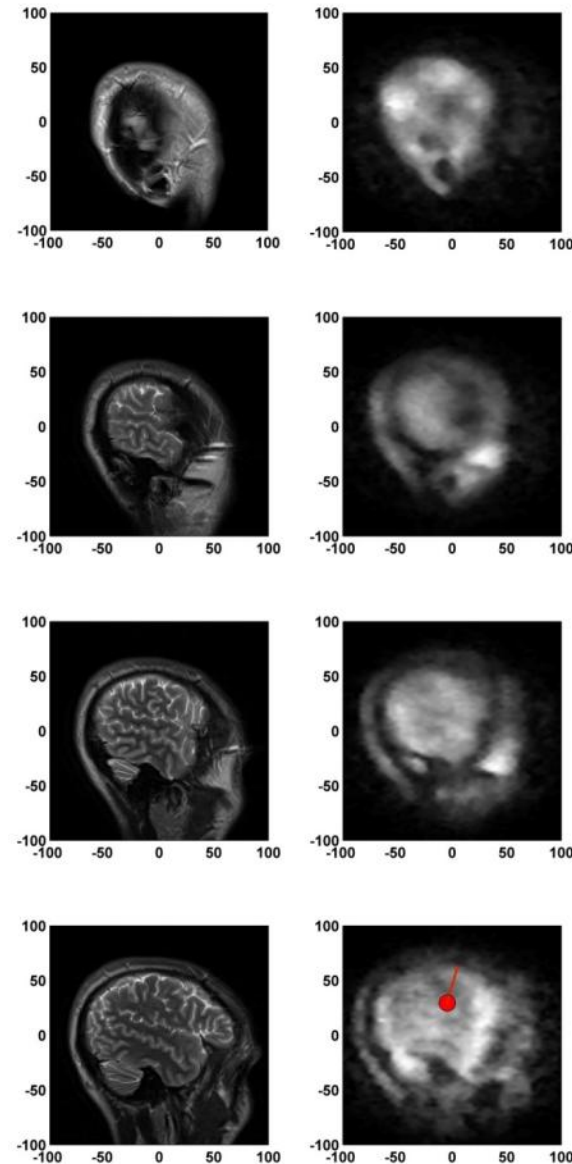


- Hospital MRI machines are huge and expensive.
- Fields are so high you can't have metal anywhere close.
- How could this go into an airport?
- This is where ULF comes in.



Ultra Low Field NMR/MRI at LANL

- Ultra low field enables integration of MRI and other brain diagnostics.
- Safe, tolerant to metal, inexpensive.
- Relies on low noise electronics and very good sensors.
- The images aren't as good, but...
- Cost is much lower and machines are much more fieldable.

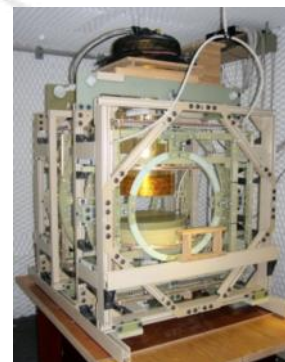




“Battlefield” and portable MRI

Design Goals / Performance Metrics

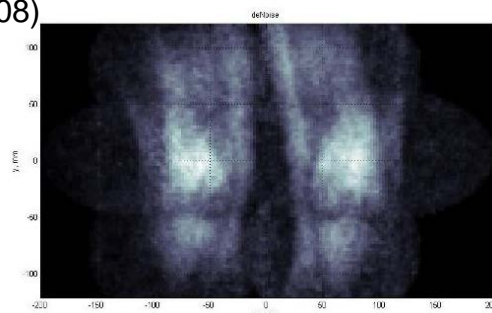
Image Quality	SNR 20, 2x2x4 mm ³
Image Time	< 20 min
Size	2x2x2 m ³
Cost	< \$500k
Cryo. refill	> 6 months
Weight	< 1 ton



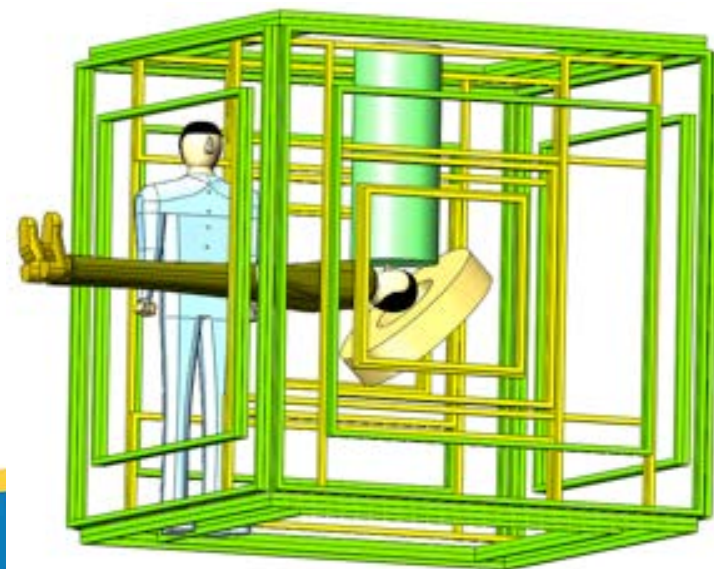
Compact MRI suitable for rapid deployment to field hospitals and emergency rooms: a path forward for a new generation of low resource MRI diagnostics.



First MRI ULF image of Espy's knees (2008)



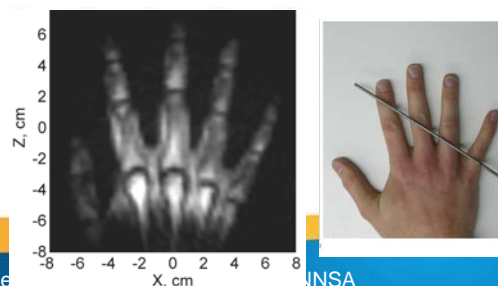
Preliminary design of the LANL “battlefield MRI” system



MRI can be delivered this way!

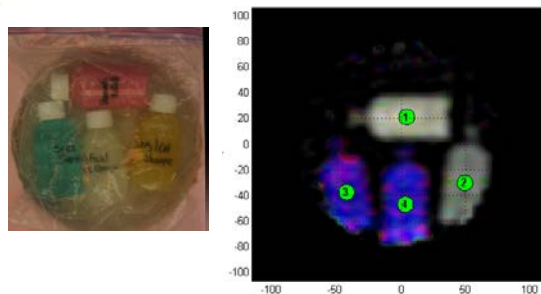
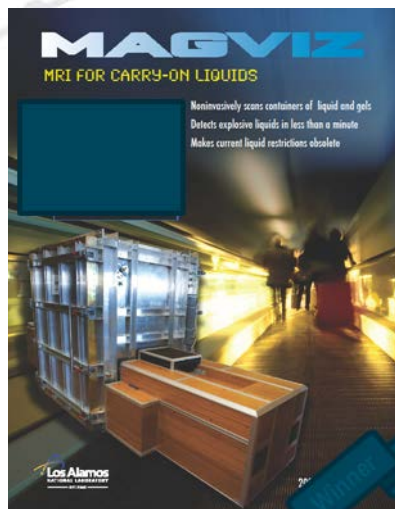


Safe in the presence of metal

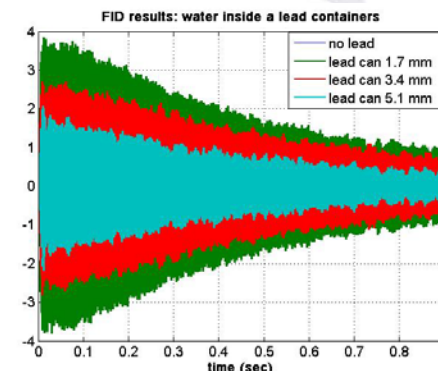




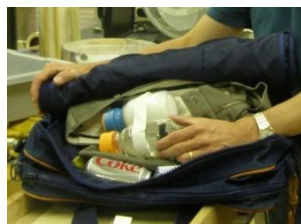
Ultra-low field NMR/MRI for detection of liquid explosives: MagViz (NMR relaxometer)



MagViz in the Albuquerque Airport, 2008



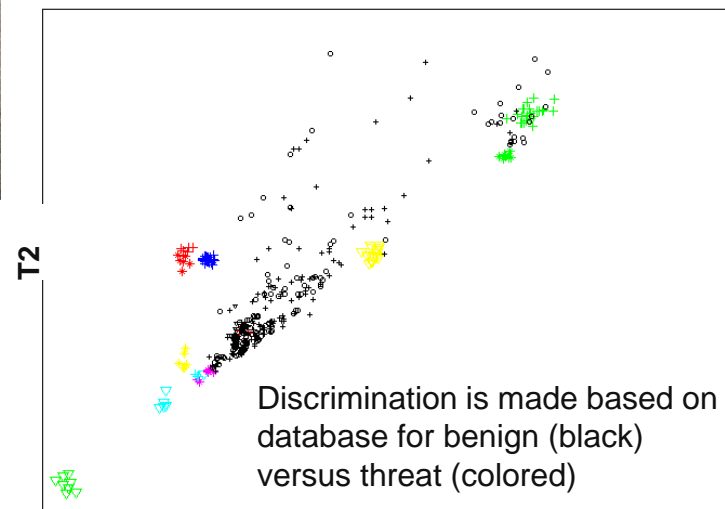
MagViz "2B" July 2010, screening large volumes



Espy et al., Supercond. Sci. Technol. 23 (2010) 034023 Ultra-low-field MRI for the detection of liquid explosives

Espy et al., "Progress on Detection of Liquid Explosives Using Ultra-Low Field MRI," IEEE Trans. Appl. Supercond., IEEE Trans. Appl. Supercond. (2011) Vol.21, iss.3 PART 1, p.530-533.

Espy et al., Applications of Ultra-Low Field Magnetic Resonance for Imaging and Materials Studies IEEE Trans. Appl. Supercond. (JUN 2009) Vol.19, iss.3, pt.1, p.835-838



Discrimination is made based on database for benign (black) versus threat (colored)

T1



Show MagViz movie from Lab YouTube Channel
<https://www.youtube.com/watch?v=xT2zncrtU-s>



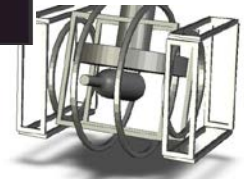
Great start, but in the real world there were problems

- Too big – no room in airports.
- Too slow – took about a minute to image a tray of liquids.
- Magnetic sensors required cryogenics (liquid helium) for cooling.





New and improved single bottle version

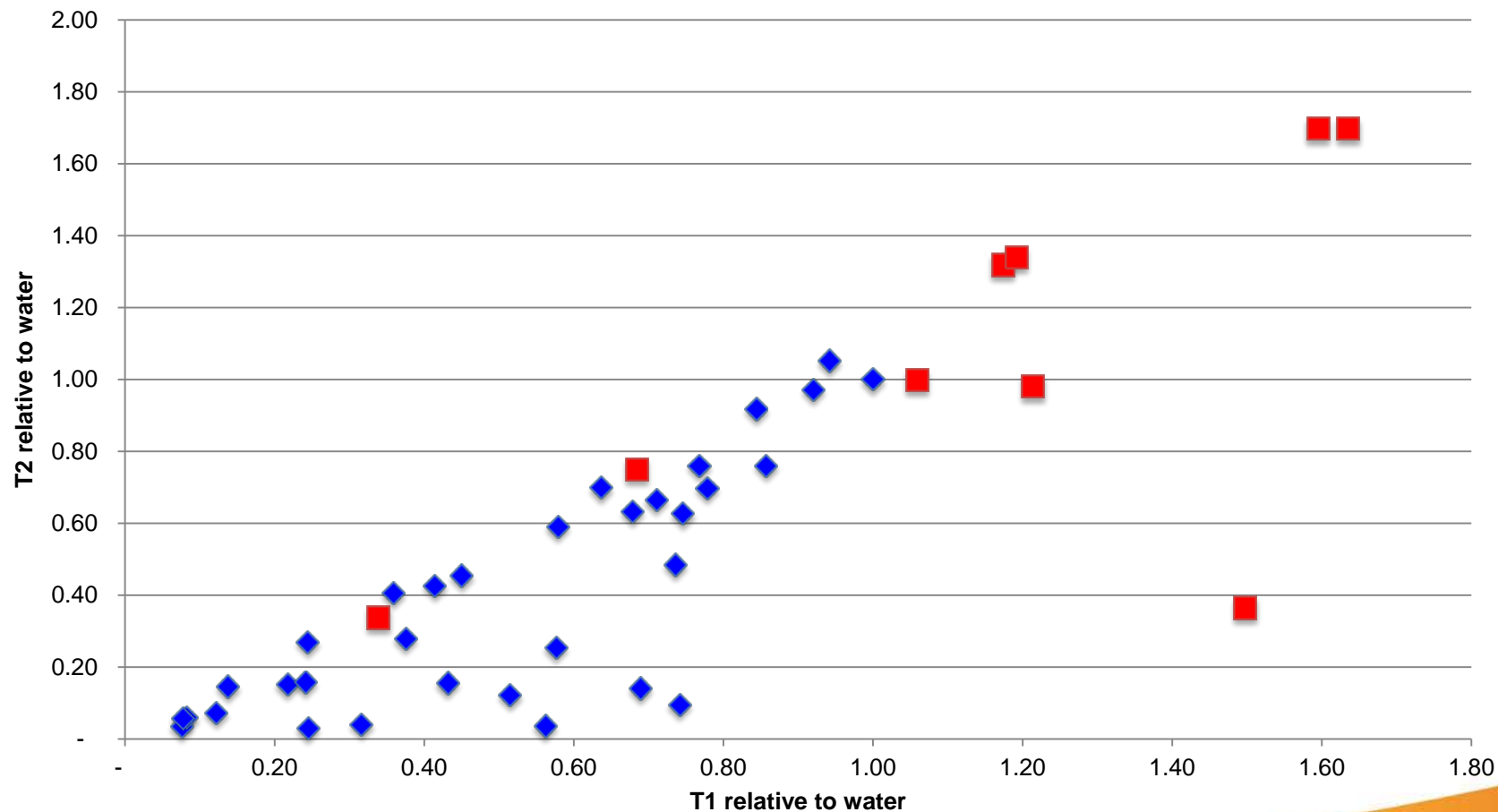


MagViz BLS, Albuquerque Airport October 2010. Screen a 3-1-1 exemption within 30 seconds.

- Small and fast and no cryogenes.
- Better than anything on the market.
- But, some liquids of more recent concern were not detectable by NMR alone.

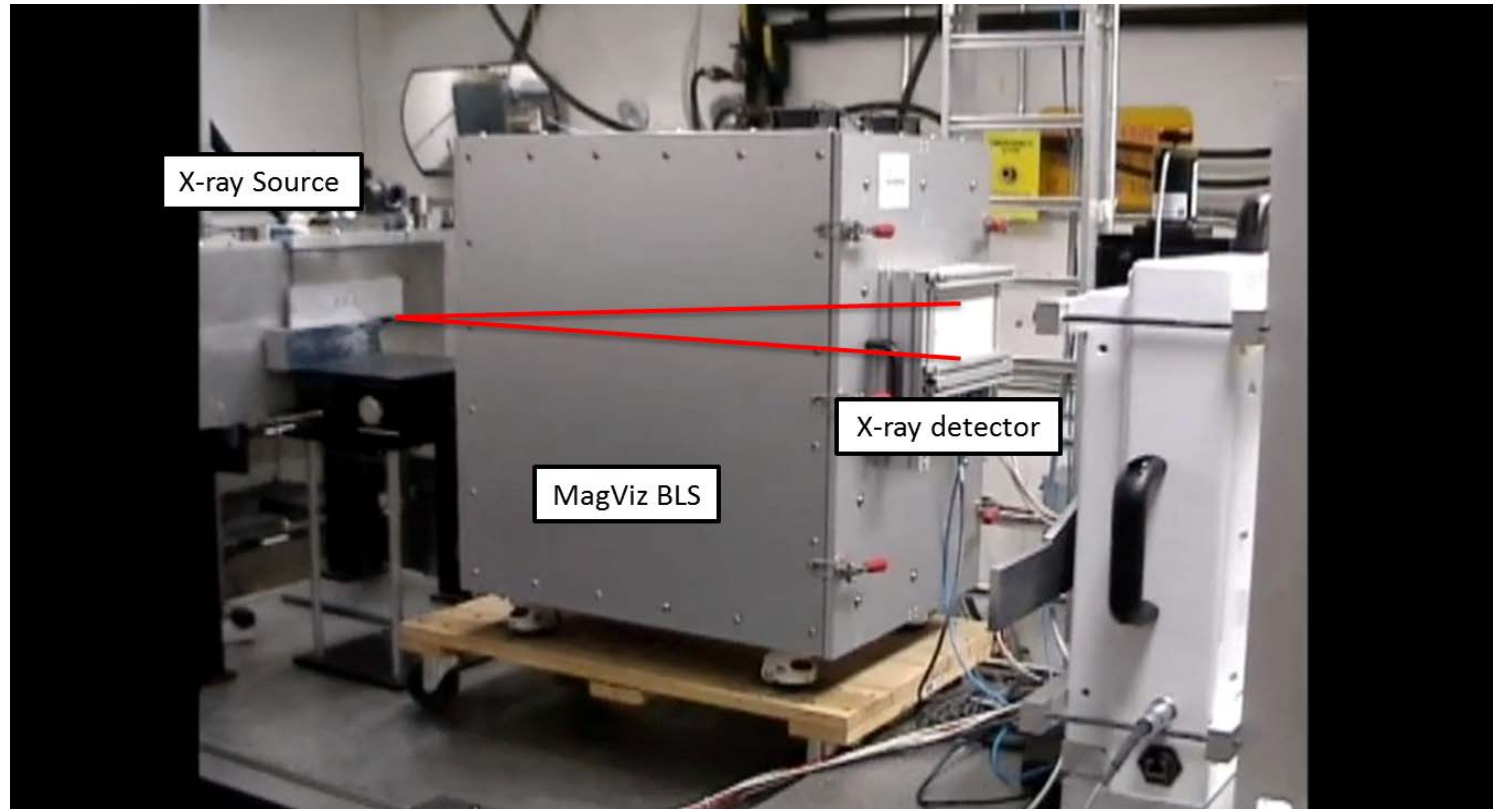


Sample Liquid “Signatures” from NMR only





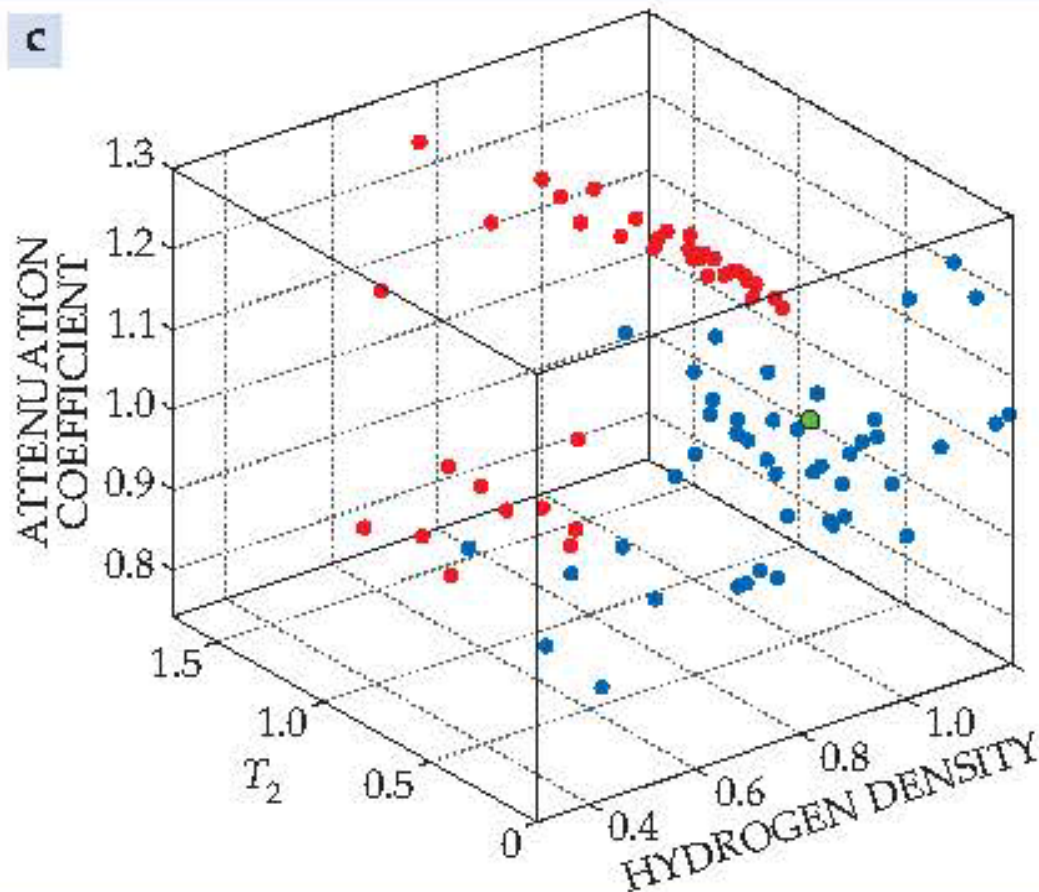
What about using X-rays again?



Setup of the MagRay demonstration experiment. The existing X-ray source is shown on the left. The X-ray detector is attached to the rear of the MagViz BLS.



Signatures in NMR + X-ray space



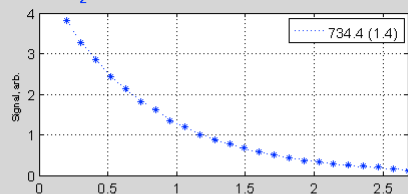


Show MagRay movie from Lab YouTube Channel
<https://www.youtube.com/watch?v=nizjDxt3F5Q&list=PL13449846A9262CF5&index=8>

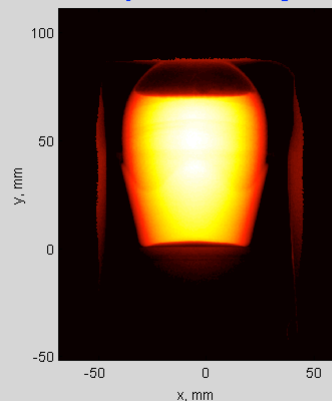


Combined ULF NMR and X-ray

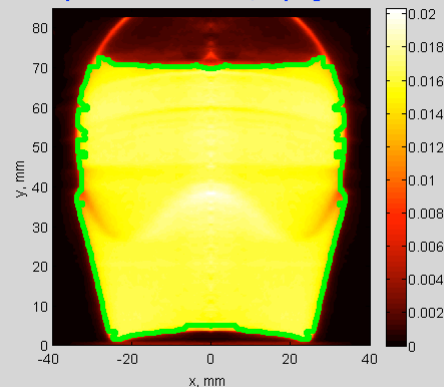
T_2 Relaxation: 734 ms at $f = 2050$ Hz



Xray Attenuation Image



Liquid Info: LAC = 0.016, ExpSig = 21.3



Classification Information

Benign

Group: Complex Water Mix

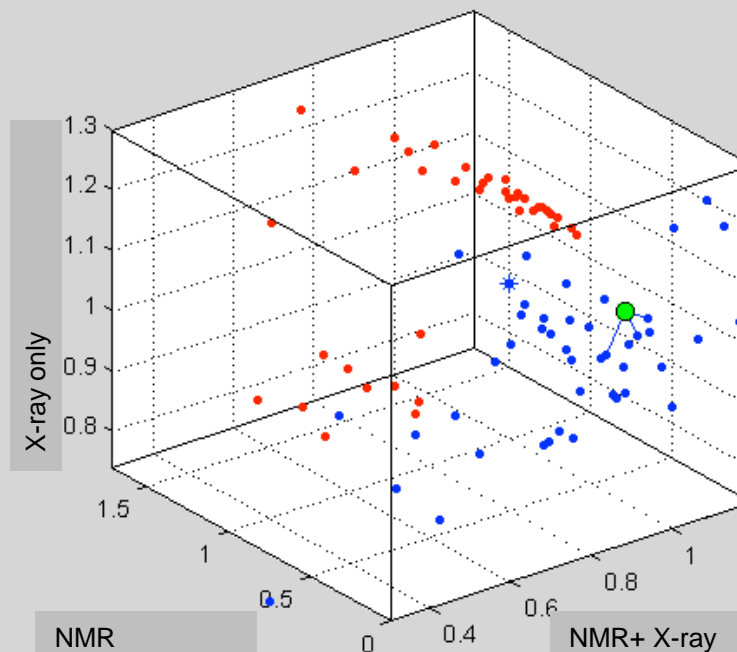
Likely: OrangeJuice / Lotion / WhiteWine

Reliability: 0.36 / 0.22 / 0.17

T_1 : 0.47, T_2 : 0.32, RNS: 1.01, LAC: 1.05

Subject ID: LimeJuice

Complex Water Mix





How it might finally look in the airport

Existing X-ray scanner

NMR add-on

